International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD)
ISSN(P): 2249-6866; ISSN(E): 2249-7978
Vol. 4, Issue 4, Aug 2014, 45-52

EXPERIMENTAL STUDY ON IN-SITU AND LABORATORY CO-RELATION OF DYNAMIC CONE PENETROMETER TEST RESULTS WITH SUB-GRADE CBR FOR LACUSTRINE (KAREWA UPLAND) AND ALLUVIAL PLAIN SOILS OF KASHMIR VALLEY

ADIL MEHRAJ[1], FIRDOUS AHAMED[2], MOHAMMAD ZUBAIR[3], IRSHAD GANI BHAT[4] & AJAZ MASOOD[5]

[1,2,3,4]UG Student, Department of Civil Engineering, SSM College of Engineering & Technology, J & K, India

[5]Research Officer, Road Research & Material Testing Laboratory, Department of Design Inspection and Quality Control, J & K, India

ABSTRACT

Geotechnical evaluation of sub-grade soil material invariably forms as one of most important steps in designing of road pavements. Sub-grade soil, whether in filling or in cutting, is required to be evaluated for critical design parameters in the form of CBR, as per IRC-37[1] and MORTH [2]. CBR is an pragmatic test which is used in design of new flexible pavements and rehabilitation of existing pavements all over the world. The conventional CBR test procedure is time consuming, relatively expensive and has generally low repeatability and/or reproducibility. This repeatability and/or reproducibility has been found critically very low for sensitive Lacustrine soils, which are locally referred as Kerawa Soils in Kashmir Valley. In order to find a solution to above problems, Dynamic Cone Penetrometer (DCP) was used in this study. The Dynamic Cone Penetrometer test (DCPT) is widely used to assess in-situ strength of undisturbed soil and compacted sub-grade materials. As such efforts in this study have been aimed at developing a reliable correlation of DCPT values and CBR for Lacustrine/sedimentary upland soil formations which can be used to facilitate quick evaluation of road sub-grades, in-place.

KEYWORDS: CBR, Dynamic Cone Penetration, Flexible Pavements, Lacustrine Soils, In-Situ Sub-Grade Strength

INTRODUCTION

DCPT was first used in South Africa as an in situ pavement evaluation technique and is widely gaining acceptance all over the world because it is economical, simple to use and is less time consuming. The DCP is used to estimate in-situ CBR (California Bearing Ratio), to identify strata thickness, shear strength of strata, and other material characteristics. For estimating the strength of soil, DCP was successfully used by Scala [3]. Researchers have tried to establish DCPT and CBR correlations [4], [5] but the conditions considered were not simulated with the actual highway conditions. Daljeet Singh *et al.* [6], Sahoo and Reddy [7] have reported a correlation between DCPT and CBR for a particular type of soil. ASTM [8] has also provided an empirical correlation between DCPT values and in-situ CBR.

$$CBR = {}^{292}/_{(DPI)^{1.12}}$$

Where *DPI* = Dynamic cone penetration index and it is equal to penetration per blow

In Kashmir valley, three typical characteristic terrain conditions are generally met, with regards to sub-grade

disposition: (a) Road sub-grades can be part of alluvial plains and flood outwash deposits over the right or left banks of river Jhelum with predominantly soft soil deposition (b) Sub-grades could be part of low to intermediate altitude upland formations in the form of Lacustrine deposits (Karewa uplands). These deposits are relatively medium to stiff soils of overall consolidated nature and relatively sensitive characteristics, and (c) Sub-grades over intermediate to high altitude formations particularly over middle and upper Himalayan ranges, exhibiting more sound depositions in the form of soil mixed with gravel, weathered /soft rock deposition, soil mixed with boulders, hard rock etc.

Barring those roads which are on high altitude areas, most of the roads have sub-grade in the form of fine grained soils like those included in alluvial plains and Karewa upland formations. The upland soils have generally been observed to be of good characteristics in terms of sub-grade strength (CBR). However the sub-grade over alluvial soils/alluvial plains generally exhibit low sub-grade strength characteristics. Apart from viewpoint of the site specific requirements for vertical alignment, sub-grades over alluvial plains, in general, are preferred in filling/embankments, in order to cause least interference of fluctuating shallow ground water table with sub-grade thereby maintaining its relatively consistent strength characteristics for sound performance as sub-grade.

As stated earlier, Karewa upland soils generally exhibit good sub-grade strength characteristics. But these soils still require in-situ and laboratory evaluation in terms of CBR strength characteristics in particular. Further it has also been observed that most of the embankments on soft soils utilize Karewa upland soils as barrow material which is compacted/remoulded to required densities for construction of soil embankments/soil sub-grade structure. Here again, these embankments are required to be evaluated for sub-grade strength in terms of CBR. As such evaluation of sub-grade soil (in natural or remoulded state) forms one of the most crucial aspect in designing a flexible pavement structure. Efforts in this experimental study were primarily aimed at developing a sound co-relation between dynamic cone penetrometer results with CBR of sub-grade soil material under in-situ and laboratory remoulded conditions. Typical representation of lacustrine soils and alluvial soils were taken from different parts of Kashmir valley, which in particular have been used as potential borrow sites, lately. Field evaluation of sub-grade soils was done in terms of cumulative number of DCPT blows for given penetration. The same potential sub-grade soils was subjected to rigorous laboratory evaluation in terms of its characterization parameters like classification, index properties, density moisture relationship, strength characteristics (CBR) etc. The various results obtained in the study were used to develop a relationship between DCPT and CBR, which may prove to be a very effective tool for highway engineers. In due course of time, if a site and soil specific strong data base is generated for above said relation (DCPT vs. CBR), it could be used to facilitate quick evaluation of road sub-grades in Kashmir Valley, based on simple tests like DCPT itself. The relations may also help enhancing highway construction quality control, ensuring long-term pavement performance, stability and may certainly help in achieving more uniform paving structural properties [6].

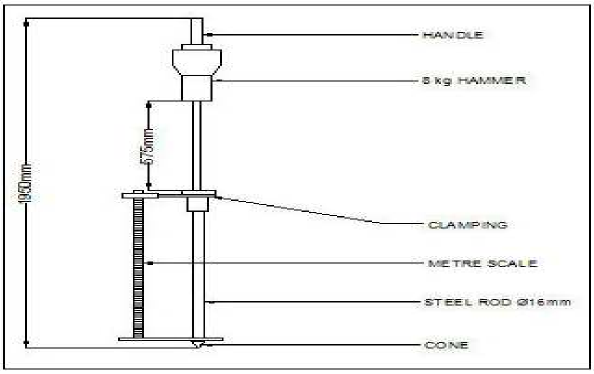

Figure 1: Dynamic Cone Penetrometer

THE DYNAMIC CONE PENETROMETER

The DCP tests conducted in this study were executed according to the procedure laid down in [8]. The DCP apparatus consists of 16mm diameter steel rod and a tempered steel cone of 20mm base diameter and a 60 degree point angle which is attached to rod. The DCP is driven in the soil by standard 8 kg hammer with a free fall of height 575 mm. The hammer correction factor for 8 kg hammer is unity. The dimensions of the DCP set-up is shown in Figure 1 (Schematic).

EXPERIMENTAL PROGRAM

Various field and laboratory identification tests were conducted on samples. A total of 17 samples of soils were tested in this study which include 9 samples of Lacustrine soils and 8 samples of Alluvial soil deposits. Lacustrine samples were collected from Pampore, Budgam and Pattan areas of Kashmir valley. Alluvial soils tested in the study were collected from Flood channel area of Rambagh area and Kashmir Government Polytechnic College Srinagar Campus. GPS co-ordinates of all the sample collection sites with designated area of their location are given in Table1.

Apart from conducting the DCP test at the sample collection sites, following routine tests were also conducted as per BIS/ASTM codal provisions/specification:

- Sieve Analysis [9], [10].
- Atterberg's limit test [11], [12].
- In-place density using Core cutter test [13], [14].
- Standard Proctor Test [15], [16].
- Laboratory CBR (of undisturbed sample and remoulded soaked sample) [1].

Dynamic cone penetrometer tests (DCPT) were carried out on the existing sub grade surface at the sample collection sites at field moisture and in-situ density to measure soil resistance. The dynamic cone penetrometer was directly placed on the sub-grade and the test was started by applying 8kg hammer blows over anvil, which would transmit the impact energy to the penetration rod, fitted with a standard DCPT cone. Soil resistance was measured in terms of penetration as mm/blow. The number of blows for 15cm, 20cm and 25cm penetration were recorded at each filed test location as $N_{c=15}$,$N_{c=20}$,$N_{c=25}$. Also laboratory CBR of undisturbed field samples CBR_{UDS}, collected in-place using core-cutter, were also conducted. Remoulded laboratory CBR of soil samples were carried after remoulding each sample at

its characteristic maximum dry density (Standard Proctor Density) in CBR mould and subjecting the sample to 72 hrs of saturation/soaking.

RESULTS AND DISCUSSIONS

The results of various laboratory tests conducted are presented in Table 2. The results of the DCP and CBR tests are presented in Table 3. With principle experimental parameters γ_d, $N_{c=15}$, $N_{c=20}$, $N_{c=25,}$ CBR_{UDS} and CBR_s, which are compiled in Table 3, the results have been plotted as depicted in Figure 1 Figure 4. All excessive data scatter has been omitted with rationality, while plotting the same. In general it has been observed that the second order polynomial provides a better fit for all the plots in comparison to linear and power fitting methods. The relation N vs. CBR_{UDS}, N vs. CBR_s

Table 1: G.P.S Co-Ordinates and Area of Collection of Soil Samples

Type of Soil Sample	Area of Site Location	Soil Sample No.	G. P. S Co-Ordinates
Alluvial	KGP College Campus, Gogjibagh, Sgr.	1	N- 34°03’35.0’’, E- 074°48’45.2”, Elevation-1600m, Accuracy- 6 m
		2	N- 34°03’32.7’’, E- 074°48’44.2”, Elevation-1602m, Accuracy- 4.5m
		3	N- 34°03’32.4’’, E- 074°48’50.5”, Elevation-1599m, Accuracy- 6m
	Flood Channel, Rambagh,Sgr.	4	N- 34°03’17.2’’, E- 074°48’19.3”, Elevation-1591m, Accuracy- 3.8m
		5	N- 34°03’25.4’’, E- 074°48’36.5”, Elevation-1606m, Accuracy- 6.2m
		6	N- 34°03’27.3’’, E- 074°48’40.5”, Elevation-1608m, Accuracy- 5.8m
		7	N- 34°03’29.0’’, E- 074°48’45.2”, Elevation-1591m, Accuracy- 5.9m
		8	N- 34°03’30.6’’, E- 074°48’51.5”, Elevation-1601m, Accuracy- 5.2m
Lacustrine	Parihaspora, Pattan.	9	N- 34°09’17.2’’, E- 074°38’44.6”, Elevation-1617m, Accuracy- 3.7m
		10	N- 34°09’16.9’’, E- 074°38’41.1”, Elevation-1626m, Accuracy- 4.5m
		11	N- 34°09’15.8’’, E- 074°38’37.9”, Elevation-1618m, Accuracy- 4.5m
	Tulbagh, Pampore.	12	N- 34°0’22.8’’, E- 074°55’59.2”, Elevation-1615m, Accuracy- 5.8m
		13	N- 34°0’24.5’’, E- 074°55’51.7”, Elevation-1608m, Accuracy- 3.7m
		14	N- 34°0’26.4’’, E- 074°55’39.7”, Elevation-1602m, Accuracy-3.4 m
	Budgam.	15	N- 34°01’27.4’’, E- 074°43’17.9”, Elevation-1627m, Accuracy- 4.7m
		16	N- 34°01’28.1’’, E- 074°43’13.2”, Elevation-1650m, Accuracy- 5.7m
		17	N- 34°01’25.4’’, E- 074°43’17.0”, Elevation-1637m, Accuracy- 4.7m

Table 2: Insitu and Laboratory Tests at Different Locations

Soil Sample No:	Insitu Dry Density, γ_d (Kn/M^3)	Field Moisture Content (%)	MDD (Kn/M^3)	OMC (%)	Silt-Clay Content (%)	L.L (%)	P.L (%)	P.I (%)
1	13.4	19.69	17.3	18.60	93.25	35.00	20.70	14.30
2	14.2	23.36	16.4	19.55	85.82	40.83	25.69	15.14
3	13.3	18.97	16.7	19.57	94.80	38.60	21.78	16.82
4	14.7	29.15	15.9	20.30	98.60	34.18	21.39	12.79
5	13.3	13.90	16.0	22.50	74.10	38.30	26.44	11.86
6	15.4	12.69	17.6	14.20	61.75	38.00	25.83	12.17
7	14.6	16.21	17.7	17.00	66.70	29.00	19.85	9.15
8	14.7	18.90	17.4	17.10	33.10	32.35	19.73	12.62
9	15.0	12.60	17.3	17.80	98.81	32.50	16.94	15.56
10	13.3	12.57	16.4	20.00	92.33	33.78	20.26	13.52
11	14.5	13.51	16.9	19.00	93.17	33.19	20.12	13.07
12	15.6	6.95	16.6	21.15	85.20	30.15	25.80	4.35
13	14.7	12.02	16.4	19.50	93.50	34.40	19.60	14.80
14	14.6	7.22	16.4	19.50	92.50	30.80	21.49	9.31
15	14.8	4.88	16.7	18.65	95.93	31.50	19.94	11.56
16	14.7	4.42	15.8	22.00	97.05	31.15	21.34	9.81
17	14.5	3.74	16.5	20.00	96.57	31.90	19.54	12.36

MDD=Maximum dry density, OMC=Optimum Moisture Content, L.L=Liquid Limit, P.L=Plastic Limit, P.I=Plasticity Index

Table 3: Results of CBR and DCP Tests

Sample No.	Insitu Dry Density, γ_d (Kn/M^3)	$N_{c=15}$	$N_{c=20}$	$N_{c=25}$	CBR_{UDS}	Cbr_s at MDD	CBR_{UDS}/γ_d
1	13.4	1	2	2	1.04	2.41	0.078
2	14.2	6	7	9	8.88	11.95	0.625
3	13.3	9	11	12	3.90	10.85	0.293
4	14.7	3	4	4	5.69	0.95	0.387
5	13.3	2	3	5	4.12	0.70	0.310
6	15.4	10	13	16	8.18	4.04	0.531
7	14.6	8	11	12	7.83	1.22	0.536
8	14.7	8	14	19	8.27	4.50	0.563
9	15.0	14	20	25	12.32	0.98	0.821
10	13.3	16	25	33	10.50	0.74	0.790
11	14.5	11	17	22	10.75	1.50	0.741
12	15.6	13	16	18	9.49	1.87	0.608
13	14.7	12	16	21	10.17	1.71	0.692
14	14.6	11	18	30	9.03	1.02	0.619
15	14.8	24	29	35	28.07	4.72	1.897
16	14.7	18	21	24	3.79	2.26	0.258
17	14.5	14	19	26	15.48	4.92	1.068

γ_d = Insitu dry density.
$N_{c=15}$ = Cumulative no.of blows for 15cm penetration.
$N_{c=20}$ = Cumulative no.of blows for 20cm penetration.
$N_{c=25}$ = Cumulative no.of blows for 25cm penetration.
CBR_{UDS} =Laboratory CBR of undisturbed field sample.
CBR_s = Laboratory CBR of soaked remoulded sample.

And N vs. γ_d shows better reliability, in terms of R^2-values, if the relation are standardised at $N_{c=20}$. The following equations are proposed:

- $CBR_{UDS} = 0.0302N_{c=20}^2 – 0.083N_{c=20} + 4.2212$
- $CBR_s = 0.0063N_{c=20}^2 - 0.0546N_{c=20} + 0.9478$

In order to filter out the effect of in-place dry density on relation between $N_{c=20}$ and CBR_{UDS}, the values of CBR_{UDS} have been normalized using values of dry density (γ_d). The normalized equation is proposed as under:

- $CBR_{UDS}/ \gamma_d = 0.0211N_{c=20}^2 - 0.0826N_{c=20} + 3.0863$
- For in-situ dry density Vs $N_{C=20}$, following equqtion is proposed:
- $\gamma_{d} = 0.6437 \ln(N_{C=20}) +12.832$

The validation of above equation for lacustrine soils has been done on basis of random in-place DCPT measurements at assorted field locations and determination of undisturbed CBR at same test locations. The standard error observed has been to the order of less than 10%. Although the results discussed in this study are applicable for specific types of valley soils considered in this study. However, if the soil is different from soil tested in the present study, one should use a discrete correlation and regression function, for data obtained for various influencing conditions of soil type, moisture content and in-situ density.

Similar power fitting methods is used in the study of Daljeet Singh etal [6]. Following relationships are observed in the study

- $Y_1= 0.1943X_m^2 - 6.7988 X_m + 71.628$
- $Y_f = 0.1918X_f^2 - 6.4346 X_f + 68.081$

Where Y_1 = Laboratory CBR at field density saturated for 24 hours.

X_m =DCPI of soil compacted in mould at field density and saturated for 24 hours in mm/blow.

Y_f = Field CBR at surface of subgrade with known dry density and artificially saturated for 24 hours.

X_f = DCPI of soil at surface of subgrade with known dry density and artificially saturated for 24 hours in mm/blow.

However some of researchers resort to log fitting method as reported in study of Sahoo & Reddy [7]. Following relationships are reported in the study:

- Log_{10} Lab CBR = 2.758 - 1.274 Log10 Lab DCP
- Ln Field CBR = 67.898 - 17.483Ln (field DCP).

Where Lab CBR = Laboratory CBR

Lab DCP = Laboratory DCPI on remoulded sample in CBR mould.

Field CBR = In-situ CBR.

Field DCP = In-situ DCPI.

CONCLUSIONS

Although above equations have been proposed considering limited data from 17 different sites from Kashmir Valley, however, these equations can be used as basis for further studies on subject matter and strengthen the data thereof.

It is proposed that further field and laboratory experimental studies may be encouraged on the topic so that reliability of above proposed equations may be improved upon and the proposed equations may be readily used to estimate various pavement system design parameters like in place density of sub-grade, undisturbed California Bearing ratio, soaked California Bearing ratio.

In present study, relatively more emphasis has been placed on evaluation of undisturbed CBR through DCP correlations because inherently the lacustrine soils in Kashmir valley are very sensitive to remoulding. Such soils are relatively consolidated and largely present a cemented disposition. Effect of in-place soaking in such soil is very minimal due to their very low permeability and high degree of consolidation. As such indirect measure of in-place and un-soaked CBR, using above established correlation, is a reliable measure of sub-grade strength, in particular.

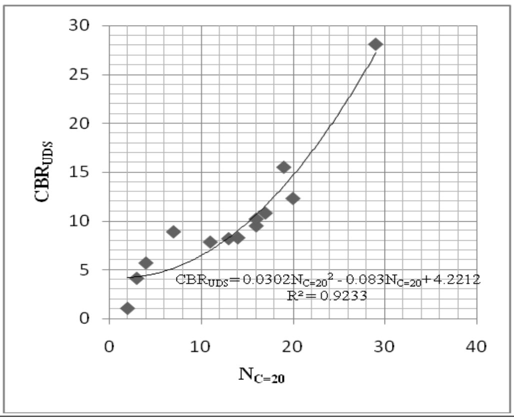

Figure 2: $N_{c=20}$ vs CBR_{UDS} Relationship

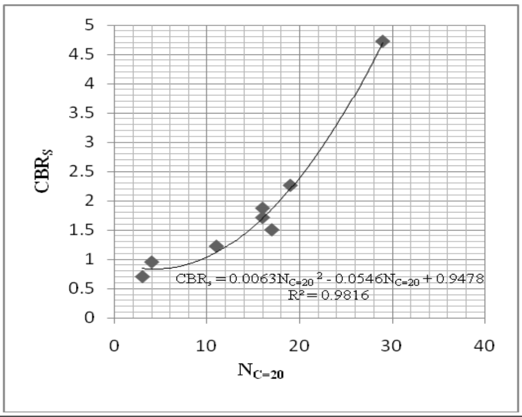

Figure 3: $N_{c=20}$ vs CBR_S Relationship

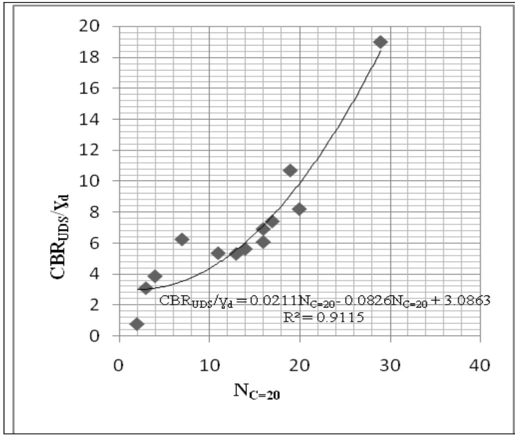

Figure 4: $N_{c=20}$ vs CBR_{UDS}/γ_d Relationship

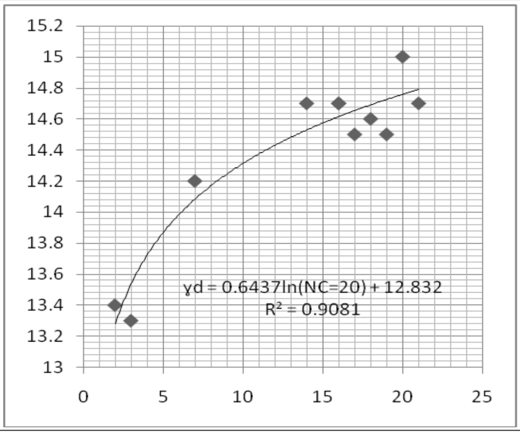

Figure 5: $N_{c=20}$ vs γ_d Relationship

ACKNOWLEDGEMENTS

This research study is the outcome of work done under guidance received from Research Officer, Road research and Material testing Laboratory, Design Inspection and Quality Control Department.

We are thankful to said the department for giving us an opportunity to gain field and laboratory knowledge on different aspects of Geotechnical engineering. We are thankful to Er.Alsana Bashir for her assistance in compilation of this paper.

Nevertheless, we heartily thank all staff members of Geotechnical Engineering Laboratory at Road Research Lab for their thorough help during our field and laboratory work.

REFERENCES

1. IRC: 37-2001. Guidelines for the design of flexible pavements.
2. IRC Special publications, “Specifications for Road and Bridge works”, Ministry of Road Transport And Highways.
3. Scala, A.J. (1956). Simple Methods of Flexible Pavement Design Using Cone Penetrometer. N.Z. Eng., 11(2).
4. Livneh, M (1989). Validation of Correlations between a number of Penetrating Tests and In situ California Tests. Transport Research Record. 1219, 56-67.
5. Haison, J.A. (1987). Correlation between California Bearing Ratio and Dynamic Cone Penetrometer Strength Measurement of Soils. Proceeding, Institution of Civil engineering, 83(2), 833-844.
6. Daljeet Singh and etal (2013). Geotechnical aspects of highway construction along the canal. Proceedings of Indian Geotechnical Conference, Roorkee.
7. P. K. Sahoo & K. Sudhakar Reddy (2009). Evaluation of Subgrade Soils Using Dynamic Cone Penetrometer. International Journal of Earth Sciences and Engineering, Vol.02, No. 04, pp. 384-388.
8. ASTM-D 6951-3 (2003). Standard Test method for use of the Dynamic Cone Penetrometer in Shallow Pavement Applications.
9. ASTM D6913-04. Standard test methods for particle-size distribution (gradation) of soils using sieve analysis.
10. IS 2720-1985 (Part 4). Grain size analysis.
11. ASTM D4318-10. Standard test method for liquid limit and plasticity index of soils.
12. IS 2720-1985 (Part 5). Determination of liquid and plastic limit.
13. ASTM D2937-00. Standard test method for density of soil in place by the drive-cylinder method.
14. IS 2720-1975 (Part 29). Determination of dry density of soils in-place by Core-Cutter Method.
15. ASTM D698-12. Standard test methods for laboratory compaction characteristics of soil using standard effort.
16. IS 2720-1983 (Part 7). Determination of optimum moisture content and dry density from proctor test.